

Missing resonance decays in thermal models

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Abstract

Detailed information on decay channel probabilities is absent for many high mass resonances, which are typically included in thermal models. In these cases, the sum over all known decay branching probabilities is smaller than 1. Due to this systematic uncertainty of the model, the exact charge conservation may appear to be violated. We estimate the corresponding number of missing charge states in the canonical ensemble formulation of the hadron resonance gas for p+p reactions at the SPS energy $E_{\text{lab}} = 158$ GeV: $\Delta B \simeq 0.16$ for baryon charge, $\Delta Q \simeq 0.12$ for electric charge, and $\Delta S = -0.01$ for strangeness. The value of the considered effect is 5-8%, which seems to be important enough to include it as a systematic error in the calculations within a hadron gas.

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The hadron-resonance gas model (HRG) allows to obtain particle multiplicities at different collision energies with a relatively good accuracy. In a simplest HRG hadrons and resonances are assumed to be non-interacting, and full chemical equilibrium is imposed. This model has just two free parameters - the temperature, T , and the baryon chemical potential, μ_B , which follow a simple analytic dependence as the function of collision energy [1, 2]. The HRG model works well for nucleus-nucleus (A+A) collisions, and even for elementary particle reactions $p + p$, $p + \bar{p}$ and $e^+ + e^-$ [3, 4]. An analytic assumption about the form of the fireball hypersurface at freeze-out allows further to obtain the p_T spectra of measured particles for the cost of just one more parameter - the ratio of the freeze-out radius and time [5–7].

Many modifications to the standard HRG exist, which improve agreement with experimental data, in particular, the one at the LHC. These include sequential freeze-out [8], a mechanism of proton suppression due to re-scattering during the freeze-out [9], introducing different proper volumes for different particles [10], or considering the possibility of pion condensation [6, 11].

A list of stable particles and resonances is a key ingredient of a HRG model. Taking into account more/missing hadron resonances helped with data description at the SPS [12] and the LHC [13]. The problem is that the list of resonances and their properties is known well only up to $m \sim 1.5$ GeV. In particular, many decay channels for measured heavy resonances are unknown. Therefore, the amount of charge that is calculated in a HRG after including only the known decays of these resonances listed in Particle Data Tables [14] is different from the one before the decays ¹. The size of the latter effect can be estimated. For the case of a proton-proton reaction the charge of the system is known exactly, $B = Q = 2$, $S = 0$. If several total 4π multiplicities are available experimentally, then their fit in the HRG within the canonical ensemble gives the thermal parameters: temperature T , system volume V , and strangeness undersaturation parameter γ_S (see Ref. [2] for details). The resulting missing charge for the p+p reactions at laboratory momentum 158 GeV/c is $\Delta B/B \simeq 8\%$ for the baryon charge, $\Delta Q/Q \simeq 6\%$ for the electric charge, and $\Delta S = -0.01$ for strangeness [2]. These numbers reflect a strongest effect of the missing decay channels probabilities for heavy positively charged baryons.

There are alternative ways to deal with the problem of missing branching ratios. One

¹ Another aspects of missing charges in p+p reactions were recently reported in [15].

option is to additionally normalize all the branching ratios to 100% [16, 17]. However, such a normalization produces some error: it artificially enhances the known channels, and, therefore, suppresses yet undiscovered channels. Another option is to assign same/similar branching ratios based on analogies to the nearest states with the same quantum numbers and known branching ratios [18].

Therefore, the value of the considered effect is 5-8%, which seems to be important enough to include it as a systematic error in the calculations within a HRG.

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